PRELIMINARY RESEARCH PROPOSAL
SUBMITTED TO THE U.S. ARMY CORPS OF ENGINEERS UNDER THE ANADROMOUS FISH EVALUATION PROGRAM
2007 PROJECT YEAR

I. BASIC INFORMATION

A. TITLE OF PROJECT

Biological Index Testing of Snake and Columbia River Dam Turbines

B. PROJECT LEADERS

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C. STUDY CODE

TSP-06-01

D. ANTICIPATED DURATION

January 1 – September 30, 2007

E. DATE OF SUBMISSION

July 29, 2005

II. PROJECT SUMMARY

A. GOALS

1. Develop a netting system to capture fish exiting the draft tube at John Day Dam with minimal injury.
2. Determine if differences in the turbine fish passage environment at John Day dam exist that may help explain differences in injury and survival of juvenile salmonids.
3. Determine the kind of injuries present in normally depth acclimated juvenile salmonids exposed to turbine passage.
4. Determine the amount of mortality present in normally depth acclimated juvenile salmonids exposed to turbine passage.
    5. Determine if types of injuries observed in dead and injured fish can be tied to different phases of turbine passage.

B. OBJECTIVES

1. Develop a net to recover fish exiting the draft tube resulting in minimal injury to fish.
2. Conduct necropsies and histology to determine sources of injury and death of run of the river juvenile salmonids after turbine passage upon exit of the draft tube at three selected turbine operating levels at JDA and IHR.

C. METHODOLOGY

We will work with net manufacturers to design and build a net and live box for recovery of juvenile salmonids as they pass out of the draft tube into the tailrace. Factors involved in design of the net will include anchor points on the dam, draft tube discharge, area of the draft tube exit sampled, live box, and anchor point of net downstream along with minimizing damage to the fish. The live box will be designed as a refuge for captured fish so flows within the box are in a range where fish can maintain position and aren't pinned against the downstream edge of the box. The live box and net will be retrieved with a crane from the draft tube deck possibly with the aid of additional rigging. Fish will be removed from the net and placed into environmentally controlled tanks. Fish will be visually examined and dead fish will be removed and necropsied. Live fish will be transported to other, appropriately sized tanks and held for 48 h to monitor delayed mortality and other indications of stress or injury. At the end of this 48 h, all fish will be necropsied. Results will be used to link injuries back to a certain cause. For example, burst swimbladders and hemorrhaged caudal veins may be indicative of damage due to pressure changes during turbine passage (as indicated by ongoing work being done by Battelle at McNary Dam). Torn opercula and missing eyes may be indicative of exposure to severe shear (Neitzel et al. 2004).

D. RELEVANCE TO THE BIOLOGICAL OPINION

The FCRPS BiOp in RPA 58 states the need to operate all turbine units at FCRPS dams for optimum fish passage survival similar to RPA 59 for operating turbines with minimum gap runners within appropriate operating ranges. Other action items addressed in this proposal are RPA 88, 89, 90, 92 and 93 to improve turbine survival of juvenile and adult fish through turbines.

III. PROJECT DESCRIPTION

A. BACKGROUND

A.1&2. PROBLEM DESCRIPTION & LITERATURE REVIEW

The Corps of Engineers is committed to increasing survival of fish passing through the turbine environments at hydropower projects on the Columbia River either by diverting the fish away from the turbines and passing them by different routes downstream or by improving turbine conditions to increase survival of fish passing through the turbine by redesigning turbines (Čada 2001) or controlling operating conditions. Under current guidelines at Columbia River Dams, turbines are operated within 1% of peak efficiency in an attempt to increase survival of salmon smolts through the turbines. Flow conditions under different operating conditions can be quite variable. Beads released into the Bonneville Dam powerhouse I 1:25 scale turbine model exhibited quite tortuous paths through the turbine model operating at the lower 1% efficiency compared with quite linear paths at maximum operation level (Weiland et al. 2005).

Radio telemetry studies conducted at John Day Dam show total survival of fish passing the dam between 87.5 and 100% (Counihan et al. 2002). The spill contribution to this survival estimate increases the total survival estimate. Turbine survival alone was not calculated but probably does not help the survival estimate for most treatments.

It is well-established that the physical stresses associated with hydroelectric turbine passage (i.e., pressure changes, shear and turbulence, or striking the turbine blade or other mechanical structures) cause injury or mortality to downstream migrant juvenile fish (Turnpenny 1998; Čada 2001). Ongoing research at McNary Dam by Battelle indicates that pressure changes present during simulated turbine exposure can result in death due to embolisms in the gills and heart and hemorrhaging of the caudal vein. Simulated turbine passage can also lead to injuries such as ruptured swimbladders which influence the behavior of fish, possibly leading to indirect mortality. Injury and death can also occur during turbine passage due to exposure of fish to shear. High values of shear are known to occur where rapidly flowing water passes near fish passage structures, including through the turbines of hydroelectric dams (Čada 2001). Neitzel et al. (2004) found that when exposed to localized, severe shear under laboratory conditions, that typical injuries to test fish included torn opercula, damaged gills, descaling, bruising, and missing or damaged eyes. Fish exposed to such conditions were also be more susceptible to predation (Neitzel et al. 2000). Normandeau (2000) also noted injuries similar to Nietzel et al. (2004) in juvenile salmon passed through turbine units.

To understand the damage that happens to fish during turbine passage, capturing fish in the tailrace is necessary. One way to achieve this is by netting. Netting studies have been conducted at various scales in the tailraces at some projects, mostly with lower discharge levels than at John Day Dam to estimate entrainment. A small scale netting project was conducted at Leaburg Dam on the McKenzie River (Fisheries Engineering Research Program USACE 1957). One of the largest netting projects conducted at the exit to a draft tube was conducted at Richard B. Russell Dam on the Savannah River (Nestler et al. 1999). Nets deployed at the exit of both draft tubes of a turbine unit covered the entire draft tube exit proving that sampling in high flow environments is possible. Methods and some basic guidelines for entrainment netting studies have been developed (Office of Technology, 1995) though it is not definitive and addresses more of the problems than solutions.

A.3. RELATIONSHIP TO ONGOING RESEARCH

This proposal has a direct link to project TSP-05-01, Pressure Acclimation Investigations to Support Biological Index Testing. TSP-05-01 has been examining the influence of turbine passage on the mortality rates and types of injuries to juvenile salmon. This project has illustrated several distinct types of injuries due to simulated turbine passage such as swimbladder rupture, hemorrhaging of the caudal vein and embolisms in the gills and heart. To date, fish testing in this project have been allowed to acclimate at depths of 0, 10, 20 and 40 ft. by allowing them access to a pressurized pocket of air. Thus fish in these experiments have the opportunity to attain neutral buoyancy at depths of 0-40 feet. However, it is not know how buoyant fish are while migrating naturally down the Columbia River. Fish may or may not be neutrally buoyant while migrating at different depths. Since fish are more likely to sustain damage during turbine passage if they are neutrally buoyant than if they are negatively buoyant, it is important to gain a better understanding of damage to juvenile fish as they naturally migrate down the Columbia River. This project will examine the injuries and mortalities of juvenile salmonids which are normally migrating down the Columbia River and encountering turbines, thus providing the most realistic picture of the relationship between turbine passage and fish injury and mortality. The types of injuries seen can then be related to those seen during simulated turbine passage to create a better understanding between turbine passage conditions and fish injury and mortality.

This proposal also has direct links to balloon tag studies that estimate mortality and evaluate external injuries to fish but not internal injuries. Investigation of internal injuries from this study may assist in the interpretation of balloon tag injury data.

B. OBJECTIVES

1. Develop a net to recover fish exiting the draft tube resulting in minimal injury to fish.
2. Conduct necropsies and histology to determine sources of injury and death of run of the river juvenile salmonids after turbine passage upon exit of the draft tube under three selected operating points at JDA and IHR.

C. METHODOLOGY

C.1. DESCRIPTION OF EXPERIMENTS

We will work with net manufacturers to design and build a net and live box for recovery of juvenile salmonids as they pass out of the draft tube into the tailrace. Factors involved in design of the net will include anchor points on the dam, draft tube discharge, area of the draft tube exit sampled, live box, and anchor point of net downstream along with minimizing damage to the fish. The live box will be designed as a refuge for captured fish so flows within the box are in a range where fish can maintain position and aren't pinned against the downstream edge of the box. The live box will also need to maintain position and posture in the water so that it won't twist and pinch off the end of the net. The net length will be dependent on tailrace flow and area of the draft tube exit sampled by the net. The larger the area of coverage of the draft tube the longer the net will be and less the taper of the net to handle the larger volume of water to be sieved. The live box and net will be retrieved with a crane from the draft tube deck possibly with the aid of additional rigging.

Units on either side of the netted turbine unit will have to be operating to aid in keeping the net fishing straight in the tailrace flows. Without adjacent units operating, the net will not fish straight due to the flow conditions in the tailrace.

To isolate damage from netting from turbine passage, some fish will be released directly into the mouth of the nets. Approximately 10 fish will be released in each of the 4 quadrants under each of the 3 different operating discharges (10 fish *4 quadrants * 3 discharges = 120 fish). This will be done for both yearling and subyearling fish.

Fish will be removed from the net and placed into tanks. Tanks will be regulated to provide temperatures which mirror the river and oxygen levels near saturation. Fish will be visually examined and dead fish will be removed and necropsied. Fish which are not dead after removal from tanks will be transported to other, appropriately sized tanks and held for 48 h to monitor delayed mortality. During this time fish will be examined for other indications of stress or injury (i. e. discoloration, lethargy, erratic or irregular swimming, or loss of equilibrium).

Necropsies will be conducted to look for injuries such as signs of gas bubble trauma (bubbles in gills and eyes), hemorrhaging of the caudal vein or hemorrhaging in other areas, embolism of the heart or gills, or rupturing of the swimbladder. External injuries such as torn opercula, bruises, cuts with visible bleeding, injured eyeballs or injured gills will also be noted (Johnson et al. 2003). Descaling and spinal fracturing will also be examined.

Necropsies will be performed immediately on fish which were dead just after removal from the net. Fish held for 48h will be sacrificed and necropsied after this period. Fish which die during the 48h holding period will be necropsied as soon as death is noted. Approximately 10-25% of necropsied fish will be sent for histological examination.

To prepare fish for histological examination, they will be fixed either in neutral buffered formalin or bouin's solution and submitted to the AquaTechnics laboratory. To examine the swimbladder and visceral organs systematically, 3-4 transverse sections will be made of the visceral cavity of the fish. In addition, a single section will be made of the saggital to parasaggital section of the head to include the pericardial cavity. A single section will be cut from each histological block and stained with hematoxylin and eosin. All organs present will be examined for anomalies and lesions. Histological work will be conducted by Aquatechnics, Inc.

Results will be used to link injuries back to a certain cause. For example, burst swimbladders and hemorrhaged caudal veins may be indicative of damage due to pressure changes during turbine passage (as indicated by ongoing work being done by Battelle at McNary Dam). Torn opercula and missing eyes may be indicative of exposure to severe shear (Neitzel et al. 2004).

C.3. STATISTICAL JUSTIFICATION FOR SAMPLE SIZE AND TESTING

Computation of sample-sizes required to accomplish statistical confidence and power objectives will not be possible in the first year of study due to the lack of prior research data in this specific area. After the first years data collection and analysis is complete, sample-size computation to accomplish statistical confidence and power objectives as specified will be possible.

C.4. METHOD OF ANALYSIS

A logistic regression model will be used as the vehicle to test for differences between survival rates and injury rates. The 4 quadrants of the turbine discharge and 3 operating conditions will be defined as factor variables.

C.5. DESCRIPTION OF TREATMENTS

Treatments will consist of 3 selected operating discharges at which a single JDA turbine unit will be operated. Operating conditions will be identified from tests using the 1:25 scale physical model at ERDC.

C.6. NUMBERS AND SOURCE OF REQUIRED FISH

This experiment will require the use of approximately 1700 run of the river fish; ~850 yearlings and ~850 subyearlings.

C.7. LIMITATIONS/EXPECTED DIFFICULTI*ES*

Netting in the tailrace of John Day Dam will prove challenging. Battelle staff have previously completed netting of fish in the tailrace of dams, though the discharge at John Day Dam is significantly greater than previous tests. Debris up to 6 inches diameter can pass through the turbine unit possibly damaging nets, adding net mending repair time to the effort.

Trying to separate damage due to capture in nets from damage during some aspects of turbine passage may be difficult. External damage which may result from shear in turbines may be confounded by damage occurring from contact with nets. To avoid this difficulty, we propose to release a number of marked fish at the base of the net. These fish will be examined to isolate the damage due to netting from damage resulting from turbine passage.

Another limitation is that computation of sample-sizes required to accomplish statistical confidence and power objectives will not be possible in the first year of study due to the lack of prior research data in this specific area. After the first years data collection and analysis is complete, sample-size computation to accomplish statistical confidence and power objectives as specified will be possible.

C.8. Expected Results and Applicability

We expect to identify specific injuries and causes of death in fish passing through turbines at JDA and IHR. We expect that we should be able to link these injuries back to specific causes and determine realistic levels of injury and mortality from turbine passage from fish normally acclimated for in river migration. We expect to be able to determine differences in injury and mortality rates based on which quadrant of the turbine exit fish are captured. These results could aid in the operation of turbines so that peak efficiency can be attained while also minimizing damage to fish.

C.8. SCHEDULE

All work at John Day Dam, including reporting through initial draft reports, will be completed in FY06 if funded by January 2006. Early funding will be needed to ensure the manufacturing of nets. Work at Ice Harbor would be conducted in FY07.

Netting and necropsies will be conducted in two blocks. The first block will be yearling fish collected in April-May. The second block will be subyearlings collected in June-July. Histology work will be completed in the 1-1.5 month period following necropsies. Letter reports summarizing the findings will be submitted to the CE. A final draft report containing any information that can be processed and analyzed within the available schedule will be submitted to the CE in September 2005. The schedule for completion of the final report will depend upon the receipt of comments from the CE.

D. FACILITIES AND EQUIPMENT

D.1. REQUIREMENTS

Nets covering part or all of a draft tube will need to be designed and built that will withstand the hydraulic conditions of the tailrace and cause minimal injury to fish. There are several commercial net companies who specialize in fishing nets that can design and build the necessary net, the concept is similar to a high speed midwater trawl. A live box will also need to be designed and built that will maintain posture and position in the flow while providing sanctuary for captured fish. Crane support will also be necessary to retrieve the net to recover fish and deploy the net in the tailrace.

All equipment for completing necropsies on fish are available with the exception of a microscope and expendable supplies.

Test fish are expected to be run of the river juvenile Chinook salmon.

D.2. JUSTIFICATION FOR SPECIAL EQUIPMENT OR SERVICES

Due to the unique application of this project special nets need to be designed and constructed that are applicable to this application.

E. IMPACTS

E.1. OTHER RESEARCH

These studies are not expected to significantly impact other research work under the assumption that required turbine operations will not affect any dam passage evaluation studies.

E.2. PROJECTS

Project support will be needed for deployment and retrieval of the net. Corp of Engineer and project support will also be needed to design and install points of attachment for the net on the dam.

The fish holding and necropsy stages of this project should be self sufficient and are not expected to require the assistance of dam project staff or to significantly impact project operations.

E.3. BIOLOGICAL EFFECTS

A number of test fish will be sacrificed for the pressure cycling study. The potential biological impact of the cable is unknown but is assumed to be negligible.

F. COLLABORATIVE ARRANGEMENTS AND/OR SUB-CONTRACTS

This sensor study will require that Battelle collaborate with AquaTechnics, Inc. for histological analysis.

IV. LIST OF KEY PERSONNEL AND PROJECT DUTIES

Thomas J. Carlson (Battelle) – Principal Investigator, technical oversight, project tasks as required, report preparation, project management.

Mark Weiland (Battelle)- Staff Scientist, fish capture techniques, report preparation, project management

Richard S. Brown (Battelle) – Staff Scientist, necropsy data analysis, report preparation, project management

C. Scott Abernethy (Battelle) – Staff Scientist, test fish animal care and experimental protocols, test fish necropsy, data analysis, report preparation.

Craig A. McKinstry (Battelle) – Staff Scientist, experimental design, statistical analysis.

Ralph Elston (Aquatechnics) – Scientist – histological analysis and interpretation

V. TECHNOLOGY TRANSFER

The principal means of technology transfer will be reporting.

VI. LIST OF REFERENCES

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Counihan, T.D., K.J. Felton, and J.H. Peterson. 2002. Survival Estimates of migrant juvenile salmonids in the Columbia River from John Day Dam through Bonneville Dam using radio-telemetry, 2000. Annual Report of Research to the U.S. Army Corp of Engineers, Portland District, Portland, Oregon.

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Weiland, M.A., R.P. Mueller, T.J. Carlson, Z.D. Deng, and C.A. McKinstry. 2005. Characterization of bead trajectories through the draft tube of a turbine physical model. PNL-14879, Prepared by Pacific Northwest National Laboratory, Richland, Washington.

VII. BUDGET

A detailed budget by the PNNL will be provided under a separate cover.